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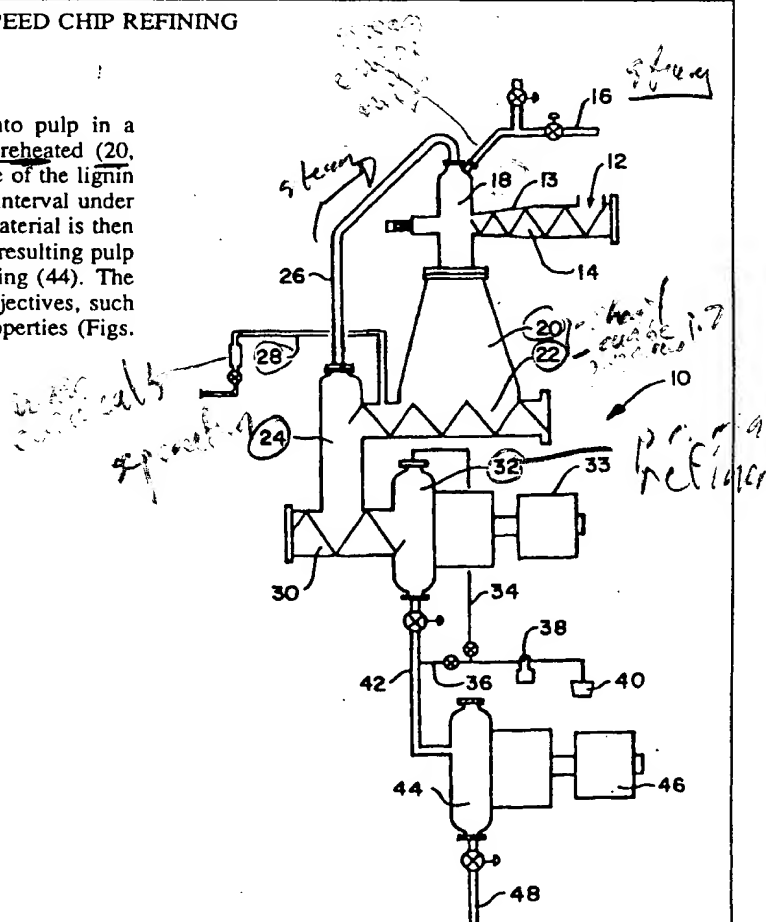
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(54) Title: **LOW-RESIDENT, HIGH-TEMPERATURE, HIGH-SPEED CHIP REFINING**

(57) Abstract

A method for refining lignocellulose-containing material into pulp in a primary refiner, preferably a disc refiner (32). The material is preheated (20, 22, 24) to a temperature greater than the glass transition temperature of the lignin in the material. The material is held at this temperature for a time interval under one minute, preferably in the range of 10-30 seconds. The heated material is then subject to high intensity refining in the refiner to produce pulp. The resulting pulp has a high quality which affords great flexibility in secondary refining (44). The preheat retention interval can be adjusted to emphasize different objectives, such as reducing total specific energy (Fig. 2) or increasing strength properties (Figs. 3 and 4).



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LOW-RESIDENT, HIGH-TEMPERATURE, HIGH-SPEED CHIP REFINING

Background of the Invention

5 The present invention is related to the field of pulp production, more particularly the invention relates to the field of refining wood chips into pulp for paper manufacturing.

Single and double disc refiners are well-known in the art of pulp production. Such refiners are typically employed in the production of pulp from lignocellulose-containing fiber material, in a two-step process
10 having primary and secondary refining. In a thermomechanical pulping (TMP) process, wood chips are fed into a pressurized pre-heater by a first plug screw feeder or first rotary valve and preheated with steam. A second screw conveyor or second plug screw feeder then discharges the chips from the pre-heater. A ribbon feeder then moves the
15 preheated chips into a refiner for initial refining into pulp. Should a plug screw feeder be used for the second feeder, the system pressures in the pre-heater and refiner can be decoupled. The pulp from the primary refiner is then introduced into a secondary refiner for further processing.

Refiners have conventionally been operated at pressures of
20 approximately 30 - 50 psi (207 - 345 kPa) and speeds of 1500 to 1800 rpm for single disc refiners and 1200 to 1500 rpm for double disc refiners. To produce pulp of desired quality, the wood chips are mixed with steam and retained in the pre-heater at a predetermined temperature and pressure prior to primary refining. The time of
25 retention, or residence time, directly affects pulp quality. Residence time is the time the chips are maintained between the first plug screw feeder and the ribbon feeder. In a decoupled system, a residence interval exists in the pre-heater and also from the second discharge plug screw feeder to the ribbon feeder. Each of these two residence
30 intervals can be regulated at a different pressure. The conveying and refining time for the chips to be moved by the ribbon feeder into the

refiner and through the refiner discs is not factored into the residence time. The reason is the short duration of the conveying and refining time. For most refiners, the conveying and refining time is less than .1 seconds.

5 An important factor in the competitiveness of disc refiners with other methods of pulp refining is the energy consumption necessary to operate the disc apparatus. Rapid increases in energy cost can render disc refiners non-competitive against other forms of pulp production from an economic standpoint. It is known in the art that increasing the
10 operational speed of a refiner reduces the total specific energy requirements for production of somewhat similar quality pulp. High speed operation in a conventional single disc refiner is greater than 1800 rpm and typically at a range of approximately 2300 to 2600 rpm. For a double disc refiner, high speed operation is over 1500 rpm and
15 typically at the range of 1800 - 2400 rpm. The higher rpm in the refiner results in what is defined as high intensity refining. Refining intensity can be expressed as either the average specific energy per bar impact or as the specific refining power. For further detailed definitions of high intensity refining, reference is made to "A Simplified Method for
20 Calculating the Residence Time and Refining Intensity in a Chip Refiner", K. B. Miles, Paper and Timber 73(1991):9. Increasing the rotational speed of a refiner disc results in increased intensities of impacts of chips with the bars on the grinding face of the disc refiner. However, high speed refining can have the undesirable side effect of
25 producing pulp that when further processed results in lower strength paper.

30 Another way of reducing energy costs in the entire paper production system is by high pressure steam recovery from the chip preheating. In conventional TMP systems, some mills require a thermocompressor or a mechanical compressor to boost the pressure of recovered preheat steam to a level necessary to supply a process

demand elsewhere in the mill. Operation of the pre-heater at high pressure results in steam of sufficient enthalpy such that the recovered preheat steam may be directly employed in a given process or economically stepped down to a level necessary to meet a process demand.

The pressure on the chips during the preheating effects pulp quality. It is important to note that high pressure and high temperature are synonymous in refining because the two variables are directly related. An important factor in refining is the temperature of the wood chips prior to primary refining in relation to the glass transition temperature of the chip lignin (T_g). This temperature varies depending on the species of the chip source.

Preheating at high temperatures, i.e., greater than the glass transition point with a conventional residence time softens the lignin to such an extent that the fiber is almost completely separated. The fibers separated under these high temperatures or pressures are largely undamaged, and they are coated with a thin layer of lignin which makes any attempt to fibrillate very difficult. The result is higher specific energy requirements and reduced optical properties of paper produced from the pulp.

Prior attempts have been made to reduce energy consumption by use of higher speed refiners and by manipulating chip and pulp temperatures above and below T_g . PCT application WO 94/16139 discloses a low energy consumption process wherein material is fed into a high speed primary refiner at a temperature below the softening temperature of lignin. The refined pulp is then held at greater than T_g for about one minute before being introduced to a second high speed refiner.

Summary of the Invention

The invention is a new and improved method of refining pulp at

the primary disc refiner in a pulp production system having one or more refiners. The method reduces energy requirements while at the same time maintaining or improving the quality of pulp as a result of employment of the novel method.

5 The method of the invention incorporates refining pulp at high intensity but significantly reducing the total specific energy requirement with no loss in pulp strength or optical properties. This result is obtained by heating the wood chips to a temperature greater than T_g with residence time less than one minute, immediately prior to primary
10 refining. In particular, it is desirable to hold the chip temperature at least 10°C above T_g for a particular species of wood chip. The chips are then fed into a high intensity refiner. This method results in at least a 20% reduction in specific energy over conventional TMP.

 In general, the residence time (R), pressure (T), speed (S) window for a particular wood species to produce improved TMP quality versus
15 convention TMP quality is 10 - 40s residence time, 75 - 95 psi pressure and a refiner speed greater than 1800 rpm for a single disc refiner and greater than 1500 rpm for a double disc refiner. In spruce/balsam chips for example, the optimum RTS window is obtained by operating a single
20 disc refiner at 2600 rpm at a pressure of 85 psi with a residence time between 10 and 30 seconds. The RTS-TMP method of the invention allows sufficient thermal softening to permit a high level of fiber development at high intensity refining but with a reduced energy expenditure.

25 The high quality pulp of the RTS-TMP method allows use of a greater variety of secondary refiners. Some secondary refiners can allow additional energy savings, or others may be employed to produce particular kinds of paper.

30 The RTS-TMP method of the invention also has uses in chemical thermal mechanical pulping (CTMP) and alkaline peroxide thermal mechanical pulping (AP-TMP).

Therefore, it is an object of the invention to provide a method of refining pulp that reduces the energy requirements for achieving a given fiber quality.

5 It is another object of the invention to provide a method of pulp production that produces higher pulp quality at a lower energy consumption than conventional TMP techniques.

It is yet another object of the invention to provide a method of producing improved pulp at the primary refiner to allow a greater number of options in the choice of secondary refining methods.

10 It is a further object of the invention to provide a method of varying the conditions for producing improved pulp at the primary refiner to achieve different desired final properties after secondary refining.

15 It is still another object of the invention to provide a method of producing pulp that requires a reduced amount of equipment.

Another object is to produce chips more receptive to initial defibrization at high intensity.

These and other objects of the invention are disclosed in the following description.

20 **Brief Description of the Drawings**

Other advantages of the invention will become more readily apparent by reference to the following drawings and description wherein:

25 Fig. 1 is a schematic diagram of a two-refiner system capable of employing the RTS-TMP method of the invention;

Fig. 2 is a graphical representation of the Freeness of pulp versus the Energy Applied for pulp refined by conventional TMP methods and by the RTS-TMP method of the invention;

30 Fig. 3 is a graphical representation of the Tensile Index versus Energy Applied for pulp refined by conventional TMP methods and by

the RTS-TMP method of the invention; and

Fig. 4 is a graphical representation of the Burst Index versus Energy Applied for pulp refined by conventional TMP methods and by the RTS-TMP method of the invention.

5

Detailed Description of the Preferred Embodiment

In Figure 1, a refining system capable of employing the RTS-TMP method of the invention is generally designated by the numeral 10. The dual refiner system 10 operates by an introduction of wood chips at a plug screw inlet port 12. A plug screw 14 drives the chips into the refining system 10 by rotating in a plug screw housing 13. A rotary valve may be substituted for plug screw 14 in some systems. Steam to heat the chips is introduced to the refiner system by line 16. The steam and chips mix in chamber 18 and enter the pre-heater 20. The heated chips are moved vertically by the inherent force of gravity to a discharge screw 22. The discharge screw 22 rotates to move the heated chips into the steam separation chamber 24. Steam is returned from the steam separation chamber to chamber 18 by means of line 26. Water or other treatment chemicals may be added to the mixture at line 28. The heat treated wood chips are then driven by a high speed ribbon feeder 30 into the primary refiner 32. The primary refiner 32 is driven by motor 33. The conveying and refining time of the chips in the ribbon feeder 30 and the refiner 32 is less than 0.1s. Bleaching agents can be introduced into the pulp at the primary refiner 32 through lines 34 and 36 by metering system 38 from bleaching agent reservoir 40.

The primary pulp is fed through line 42 to the secondary refiner 44, the refiner being driven by motor 46. The refined pulp of the secondary refiner 44 is transferred by line 48 to other apparatus for further processing into a final product.

The residence time is the travel time for the chips to be moved between the plug screw feeder 14 and the ribbon feeder 30. In a

decoupled system, a plug screw feeder would replace the discharge screw 22. The residence time at high pressure would then be defined as the duration between screw 22 and the ribbon feeder 30. With this alternative of the RTS-TMP invention, a preheating vessel is not necessary. In a typical conventional refining method, the temperature of the chips prior to primary refining is maintained below T_g .

The temperature below T_g prevents excessive softening of the lignin in the wood chips. This prevents a high degree of separation at the middle lamella, which would otherwise result in a high degree of separated fibers coated in a layer of lignin which renders very difficult any attempt to fibrillate the fiber structure.

High pressure refining may be desirable to allow economical steam recovery for further uses in process demand. The results of a comparison of conventional TMP, and TMP at high pressure are shown below.

Test 1

EFFECT OF PRESSURE AT 1800 RPM

		Conventional TMP	High Pressure TMP
20	PRIMARY		
	RPM	1800	1800
	Pressure (kPa)	276	586
	Residence Time (Seconds)	150	150
25	Specific Energy (kWH/ODMT)	705	505
	SECONDARY PULP		
	Total Specific Energy (kWH/ODMT)	1836	2185
	Freeness (ml)	194	179
	Bulk	3.04	2.73
30	Burst	1.7	2.1
	Tear	9.3	9.9
	Tensile	36.3	41.0
	% Stretch	1.83	1.90
	T.E.A.	28.05	32.78
35	Brightness (Physical Sheets)	46.5	43.1
	Scattering	47.0	45.2
	Opacity (%)	94.3	95.4
	Shive Content (%)	1.28	0.40
	+ 28 Mesh (%)	48.5	37.9

With reference to the preceding test, the Total Specific Energy for the final production of pulp using a high pressure method over the conventional method is increased by 19%. The optical quality of the sheet decreased by 3.4%. The decrease in optical quality was a result of discoloration of chromophores in the lignin due to the extended residence time at the higher pressure.

Conventionally, the primary refiner 32 can be either a single disc or a double disc design. The conventional primary refiner is operated at a speed of 1500 - 1800 rpm for a single disc and 1200 - 1500 rpm for a dual disc refiner. The range is due to the frequency of the AC power source, 60 Hz in North America and 50 Hz in most of Europe. Disc speeds over 1800 rpm in single disc designs at either operating frequency is considered high speed refining. For double disc designs, speeds over 1500 rpm at either frequency are considered high speed refining.

The following test compares conventional TMP and high speed TMP. The high speed TMP in this test was performed at 2600 rpm.

Test 2
EFFECT OF SPEED AT CONVENTIONAL REFINING PRESSURE

	Conventional TMP	High Speed TMP
PRIMARY		
RPM	1800	2600
Pressure (kPa)	276	276
Specific Energy (kWH/MT)	974	876
Residence Time (Seconds)	150	150
SECONDARY PULP		
Total Specific Energy (kWH/ODMT)	2045	1621
Freeness (ml)	153	178
Bulk	2.83	3.05
Burst	2.0	1.7
Tear	9.2	9.4
Tensile	38.3	40.7
% Stretch	1.83	1.86
T.E.A.	31.1	29.3
Brightness (Physical Sheets)	46.7	48.0
Scattering	48.6	49.1
% Opacity	94.5	94.3
Shive Content (%)	1.64	2.48
+ 28 Mesh (%)	35.5	35.4

Raising the operating speed of the refiner to 2600 rpm and leaving all other parameters the same results in pulps produced in the primary refiner with similar properties to that of the conventional TMP.

The increased refiner speed results in a reduction of 15% in required
5 Total Specific Energy.

Combining high speed refining and high temperature preheating at a high residence time results in a commercially unacceptable refining process. There is a loss of plate gap between the discs of the primary refiner and an unacceptable loss of brightness in the pulp. Excessive
10 thermal softening at high pressure prevents applying reasonable levels of specific energy in the primary refiner.

However, it was found that decreasing the residence time for high pressure, high intensity refining, could produce a pulp of acceptable quality and at lower energy requirements. Three examples
15 were tested with decreasing residence times. The results are shown in the following Test 3. The results show that residence times less than one minute for temperatures greater than T_0 can avoid the poor pulp quality of high pressure, high intensity refining with a conventional high residence time. The preferred resident time of the invention is less than
20 40s.

Test 3

EFFECT OF RESIDENCE TIME AT HIGH PRESSURE AND HIGH INTENSITY REFINING

	<u>Ex.1</u>	<u>Ex.2</u>	<u>Ex.3</u>
25 PRIMARY			
RPM	2600	2600	2600
Residence Time (Seconds)	120	24	13
Specific Energy (kWH/MT)	570	610	536
30 SECONDARY PULP			
Total Specific Energy (kWH/MT)	1817	1848	1687
Freeness (ml)	168	185	148
Bulk	2.71	2.89	2.83
Burst	1.9	1.8	2.1
35 Tear	9.4	9.4	9.3
Tensile	41.1	37.6	42.1
% Stretch	1.93	1.61	2.06

	<u>Ex.1</u>	<u>Ex.2</u>	<u>Ex.3</u>
T.E.A.			
Brightness (Physical Sheets)	33.8	26.5	36.5
Scattering	43.8	46.6	46.5
Opacity	46.5	48.9	48.2
Shive Content (%)	95.4	94.3	95.1
+ 28 Mesh (%)	0.60	0.73	1.24
	31.5	33.3	37.7

In the above Test 3, using spruce chips as a test lignocellulose-containing material, the optimum residence time is thirteen seconds although the range 10 - 30 seconds appears to offer significant advantages. The result of this residence time at high pressure is sufficient thermal softening of the wood chips such that the fiber is more receptive to initial fiberization at high intensity without completely softening the fiber and coating the fiber with lignin. The majority of broken fibers in TMP pulps have been initiated during the initial defiberization of the chips in the primary refiner 32. The objective here is to establish an improved primary refiner pulp fingerprint at a reduced specific energy requirement. This is the RTS-TMP method of the invention.

The RTS-TMP method of the invention is compared with conventional TMP methods in Test 4.

Test 4

COMPARISON OF BASELINE AND RTS-TMP PULP PROPERTIES AND ENERGY REQUIREMENTS

	Conventional TMP 1	Conventional TMP 2	RTS-TMP
PRIMARY			
RPM	1800	1800	2600
Pressure	276	276	586
Retention (Seconds)	150	150	13
Specific Energy (kWH/ODMT)	1243	705	536
SECONDARY			
Total Specific Energy 2030	2011	1567	
Freeness (ml)	148	148	148
Bulk	2.82	2.85	2.83

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		Conventional TMP 1	Conventional TMP 2	RTS-TMP
	Burst	1.8	2.0	2.1
	Tear	9.3	8.9	9.3
5	Tensile	37.1	38.6	42.1
	% Stretch	1.66	1.93	2.06
	T.E.A.	28.6	32.0	36.5
	Brightness			
	(Physical Sheets)	46.6	46.1	46.5
10	Scattering	47.0	52.3	48.2
	% Opacity	93.7	94.8	95.1
	Shive Content	2.18	1.44	1.24
	% +28 Mesh	32.1	37.7	37.7

15 The system temperatures of conventional TMP of columns one and two, and RTS-TMP of column three are 132°C and 166°C respectively.

20 With reference to Test 4, it can be observed that the specific energy required for the base line refining is decreased by use of the RTS-TMP method. The results of two different runs of the conventional method are shown. The two conventional runs are at different power splits between the primary and secondary refining. The total specific energy measured in kilowatt hours per metric ton decreased from approximately 2,000 to approximately 1,500, for a decrease of 22.4%. The freeness of the pulp remained the same, even though the energy

25 required for refining decreased.

In addition to the decreased energy requirements, certain pulp properties are improved by use of the novel RTS-TMP method of the invention over conventional TMP.

30 The tensile index of the pulp measured in Newton meters per gram is increased by use of the RTS-TMP method over the conventional TMP method (Fig. 3). Compared at a similar specific energy, the RTS-TMP averaged approximately 8Nm/g higher tensile index. Similarly, the burst index versus the energy applied is increased by use of the RTS-TMP method over the conventional TMP method of pulp refining (Fig.

35 4). Compared at a similar specific energy, the RTS-TMP averaged

approximately 0.6 kPa.m²/g higher burst index over conventional TMP.

The improved pulp quality as a result of the RTS-TMP allows greater flexibility in the type of secondary refining that can be employed. In some cases, no secondary refining will be required. The
5 pulp from the primary refiner can be immediately processed into paper. In most cases, however, secondary refining will be required to obtain pulp of the necessary quality for the paper requirements. The primary
10 pulp of RTS-TMP has less broken fibers and fracture zones. This improved pulp fingerprint is less prone to fiber degradation permitting energy saving high intensity refining to be used in the second stage. The improved pulp quality allows a wider variety of secondary refining. Choices of secondary refiners 44 include both low consistency refining (LCR) and high consistency refining (HCR). Low and high consistency
15 refer to the percentage of solids to total material in the pulp. HCR is typically between 25 - 50% solids, and LCR is less than 10% solids. The HCR processes available include conventional HCR, high speed HCR and thermal HCR. As a result of the RTS-TMP method of the invention, energy usage is decreased 22.4%, and furthermore, additional energy savings can be realized by steam recovery at high pressure. These
20 improvements in energy requirements are with a further benefit of improved pulp quality.

The RTS-TMP method of the invention results in improved newsprint from the refined pulp. A comparison of newsprint produced from three methods of pulp production is shown in Test 5.

13

Test 5

100% TMP NEWSPRINT PROPERTIES PRODUCED FROM
BASELINE, HIGH SPEED AND RTS-TMP PULPS

5	<u>Process</u>	<u>Conventional TMP*</u>	<u>RTS-TMP**</u>	<u>High Speed***</u>
	Caliper (mm)	0.147	0.150	0.147
	Density (g/cm ³)	0.335	0.339	0.331
	Brightness	40.1	42.8	43.2
	Opacity	84.2	85.0	80.9
10	% Stretch-MD	3.34	3.12	3.12
	% Stretch-CD	3.89	4.15	4.45
	Tensile Index	21.13	22.33	17.49
	(N.m/g)-MD			
15	Tensile Index	9.43	9.82	8.48
	(N.m/g)-CD			
	Breaking Length	6463	6831	5350
	(m) MD			
	Breaking Length	2886	3004	2593
	(m) CD			
20	Burst Index	0.59	0.62	0.55
	(kPa.m ² /g)			
	Tear Index	6.95	6.97	6.46
	(mN.m ² /g) MD			
25	Tear Index	6.76	7.62	6.72
	(mN.m ² /g) CD			

* 1800 RPM, 150 seconds at 276 kPa

** 2600 RPM, 13 seconds at 586 kPa

*** 2600 RPM, 150 seconds at 276 kPa

Test 5 represents newsprint produced from secondary refiner discharge. Pulps of all three methods of primary refining were subjected to the same method of secondary refining before manufacture into newsprint. Newsprint produced from the RTS-TMP method (column 2) had no reduction in the optical properties of brightness and opacity over the newsprint made using conventional TMP (column 1). The high speed refining at conventional pressure and residence time (column 3) had the lowest bonding strength sheet properties.

The foregoing data provide the basis for an RTS control system in which the retention interval is adjusted according to the relative importance of particular pulp properties or process conditions. This interval is adjustable in a decoupled system of the type shown in Figure

1, for example, by the speed of the plug screw feeder 22. With respect to Test 3 and Figures 2-4, one type of material (spruce chips) experienced different residence intervals of 24 or 13 seconds, before being introduced into the primary refiner, with resulting differential effects on energy, freeness and strength related properties. These data clearly show that properties such as freeness comparable to conventional refining can be achieved via RTS with a substantial reduction in energy (Figure 2). At energies comparable to conventional refining, significantly improved strength can be achieved using the 24 second residence interval, relative to both the 13 second interval and to conventional refining (Figures 3 and 4).

While a preferred embodiment of the foregoing method of the invention has been set forth for purposes of illustration, the foregoing description should not be deemed a limitation of the invention herein. Accordingly, various modifications, adaptations and alternatives may occur to one skilled in the art without departing from the spirit and the scope of the present invention.

CLAIMS:

1. A method of producing pulp from lignocellulosic containing fiber material in a refining system having a primary refiner, characterized by:
heating the fiber to greater than the glass transition temperature of
5 the lignin in the fiber;
maintaining the temperature of the fiber at greater than said glass transition temperature for a time interval of less than one minute; and
refining the heated fiber in the primary refiner at high intensity.
- 10 2. The method of claim 1, characterized in that the refiner is a disc refiner.
3. The method of claims 1 or 2, characterized in that the heating of the fiber is accomplished by use of saturated superatmospheric steam.
- 15 4. The method of claim 3, characterized by recovering said steam after said steam has heated said fiber.
5. The method of any one of claims 1-4, characterized in that the fiber is maintained at a pressure of about 75 - 95 psi.
6. The method of any one of claims 1-5, characterized in that the pressure is maintained in the range of 80 - 90 psi.
- 20 7. The method of any one of claims 1-6, characterized in that the time interval is less than 40 seconds.
8. The method of any one of claims 1-6, characterized in that the time interval is between about 10 and 30 seconds.

9. The method of any one of claims 1-8, characterized in that said primary refining is at high consistency.

5 10. The method of any one of claims 1-9, characterized in that the refiner includes a refining disc that rotates at a speed greater than 1800 rpm.

11. The method of claim 10, characterized in that the refiner disc rotates at a speed greater than 2300 rpm.

10 12. The method of any one of claims 1-9, characterized in that the refiner is a double rotating disc refiner operating at a speed greater than 1500 rpm.

13. The method of any one of claims 1-12, characterized by subjecting the pulp produced in the primary refiner to a secondary refining step of defibrating by a rotating disc.

15 14. The method of claim 13, characterized in that the secondary step is performed at low consistency.

15. The method of claim 13, characterized in that the secondary step is performed at high consistency.

16. The method of claim 15, characterized in that the secondary step is performed at high speed.

20 17. The method of any one of claims 13-16, characterized in that the secondary step is performed by a rotating disc refiner distinct from the primary refiner.

18. The method of any one of claims 13-17, characterized in that the pulp from the primary refiner is fed into the secondary step at a temperature lower than the glass transition temperature of the lignin.

5 19. The method of any one of claims 13-17, characterized in that the pulp from the primary refiner is fed into the secondary step at a temperature higher than the glass transition temperature of the lignin.

20. The method of any one of claims 13-19, characterized in that the material in the secondary refiner is subjected to high intensity defibrating.

10 21. The method of any one of claims 1-20, characterized in that the primary refiner imparts energy to the material at a rate in the range of 400 - 800 kWH/ODMT.

15 22. The method of any one of claims 1-21, characterized in that the fiber is heated to greater than the glass transition temperature, in a pressurized screw conveyor (22) upstream of a feeder mechanism (30) of the primary refiner (32) and

20 said time interval is dependent on the conveyance time through said pressurized screw conveyor (22) to the feeder mechanism (30) of the primary refiner.

23. The method of claim 22, characterized in that said time interval is adjusted by varying the speed of said screw conveyor (22).

25 24. The method of any one of claims 1-23, characterized in that for a given lignocellulosic material, said time interval is variable between a relatively long time interval at relatively high total applied energy for achieving maximum strength, and a relatively short time interval at

relatively low total applied energy, for minimizing applied energy to achieve a desired freeness.

25. The method of claim 24, characterized in that said relatively long time interval is about 24 seconds.

5 26. The method of claim 24 or 25, characterized in that said relatively short time interval is about 13 seconds.

27. The method of any one of claims 24-26, characterized in that said relatively high total applied energy is above about 1800 kWh/ODMT.

10 28. The method of any one of claims 24-27, characterized in that the relatively low applied energy is less than about 1650 kWh/ODMT.

29. The method of any one of claims 1-21, characterized in that the fiber is heated to greater than the glass transition temperature, in a preheating subsystem (20,22,24) immediately upstream of the primary refiner (32),

15 said time interval is dependent on the conveyance time through said preheating subsystem, and

the conveyance time is adjustable in the range of at least 10-30 seconds.

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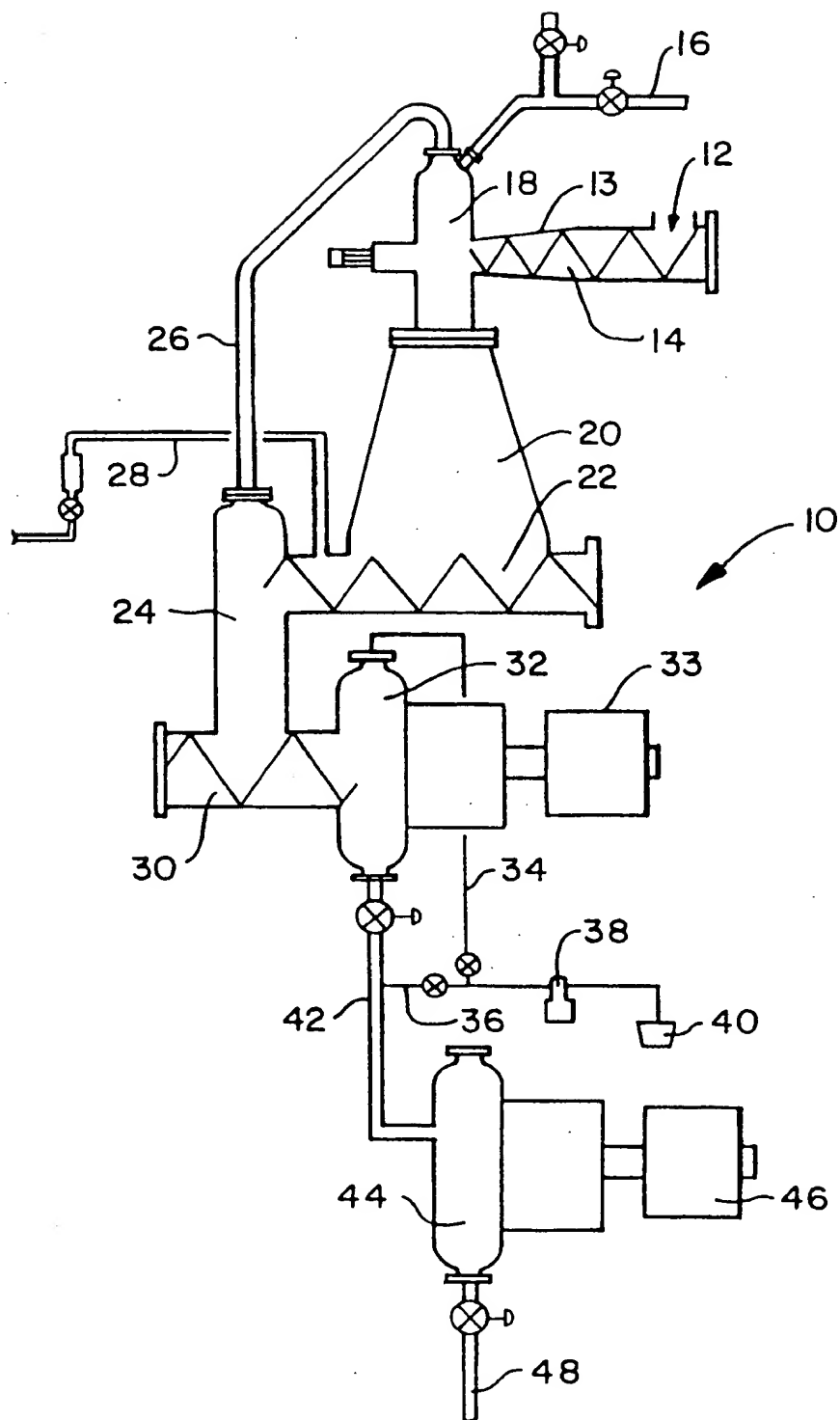


Fig. 1

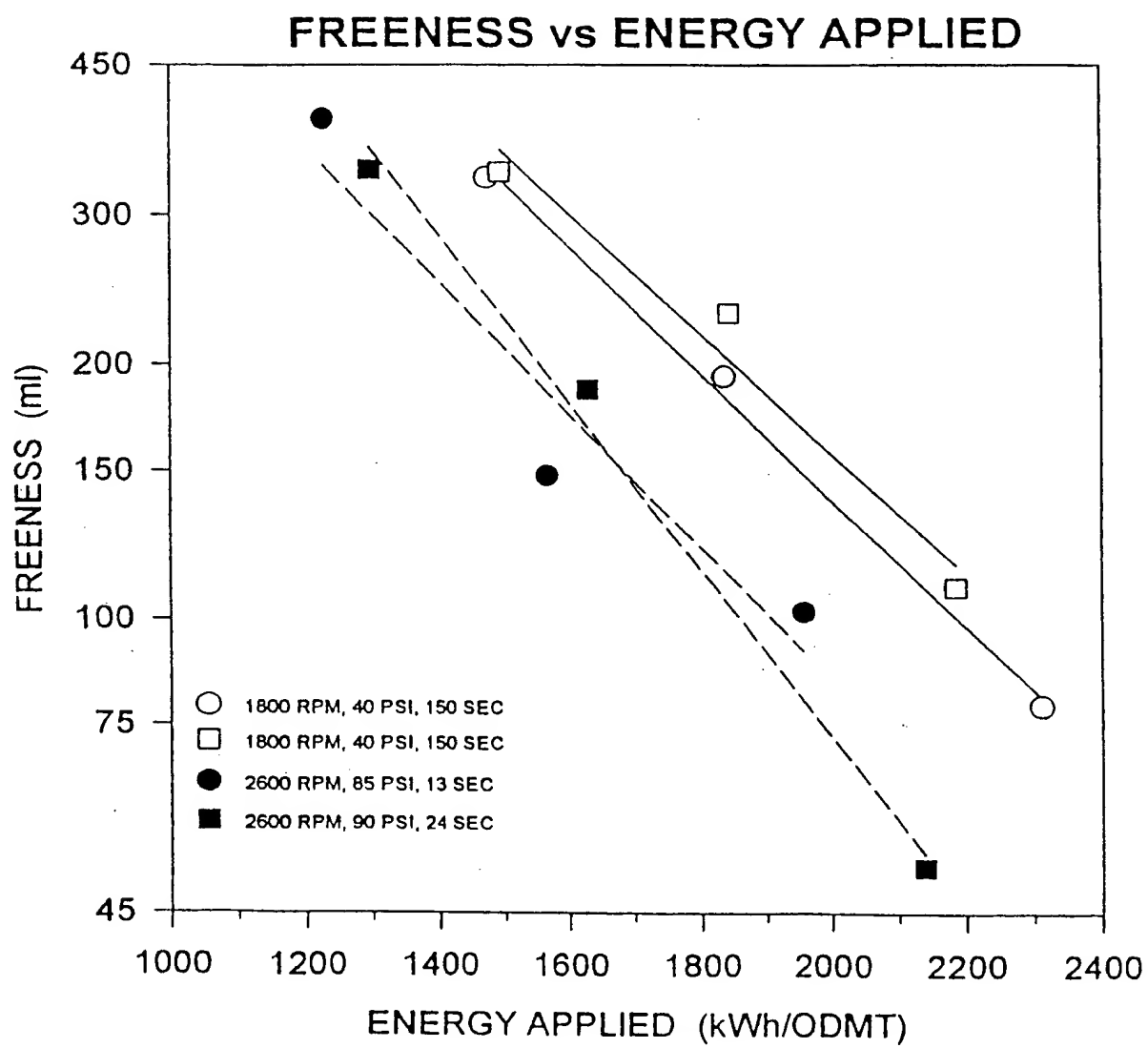


Fig. 2

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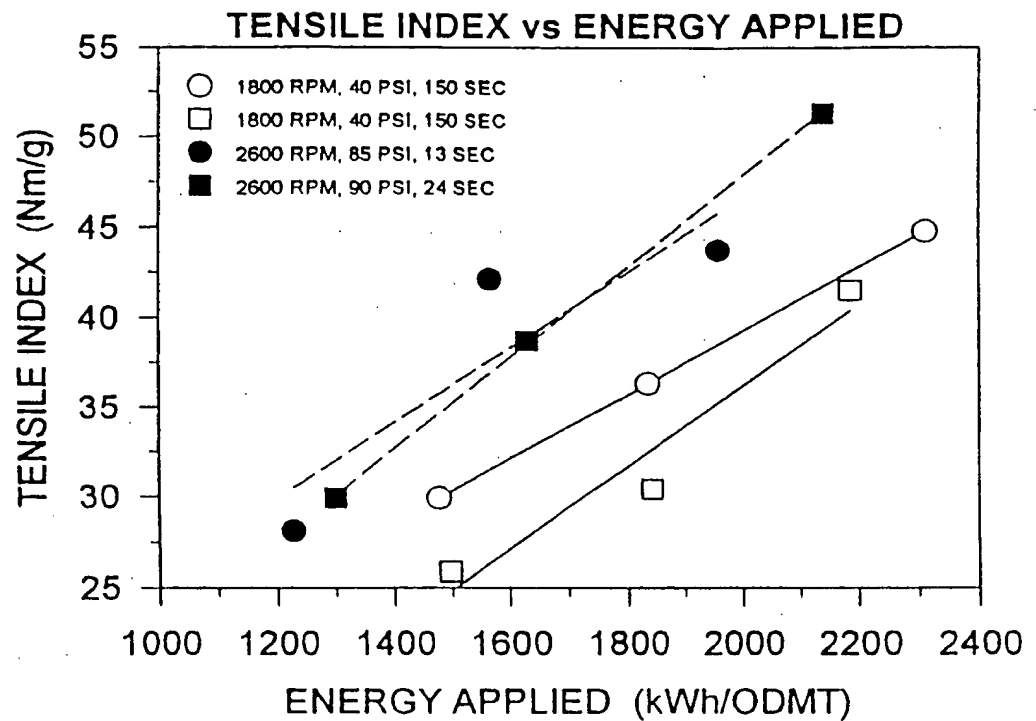


Fig. 3

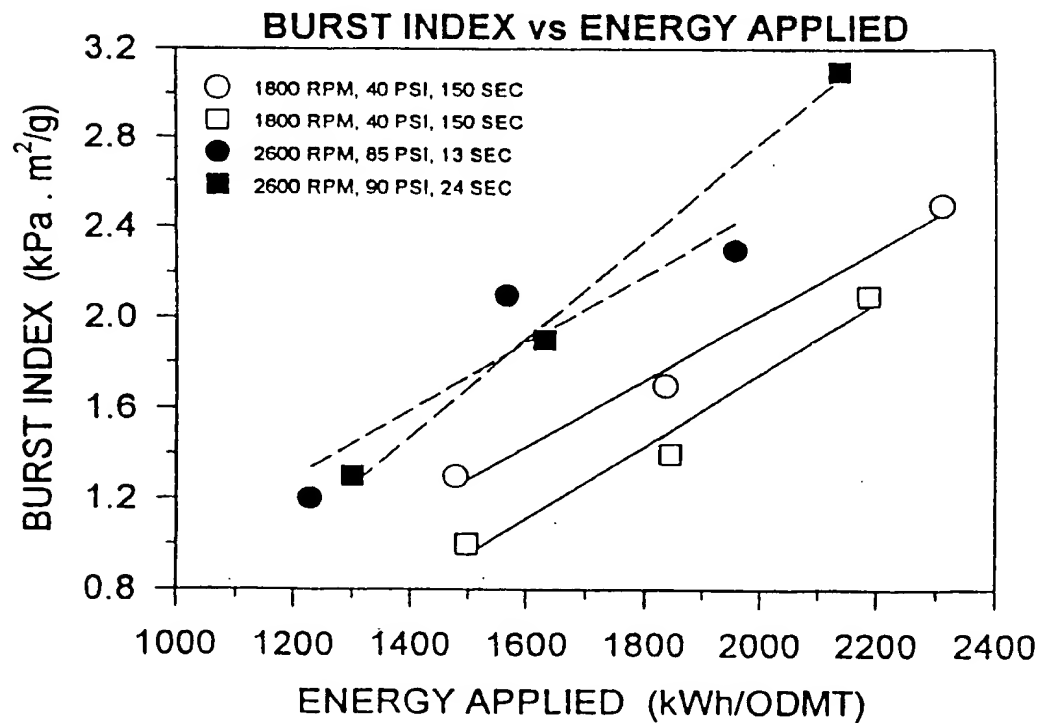


Fig. 4

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 96/09784

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 D21B1/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 D21B D21D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO,A,91 12367 (SCA RESEARCH AB) 22 August 1991 see the whole document ---	1,2,7,8
P,A	WO,A,95 34711 (MÖLNLYCKE) 21 December 1995 see the whole document ---	1,2,9
A	FR,A,2 356 763 (AMERICAN DEFIBRATOR INC.) 27 January 1978 -----	

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents :

- *A* document defining the general state of the art which is not considered to be of particular relevance
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- *P* document published prior to the international filing date but later than the priority date claimed

- *T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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Date of the actual completion of the international search

30 October 1996

Date of mailing of the international search report

21. 11. 96

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De Rijck, F

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/US 96/09784

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